Chapter 10
Ice Jam Flooding in the United States

10-1. General

Flooding and flood-related events cause greater damage and more fatalities than any other natural disaster. About 80 percent of all presidential disaster declarations are the result of flooding (Federal Emergency Management Agency 1992a). Flood damages averaged $3.3 billion and flood-related fatalities averaged about 100 annually over a recent 10-year period (U.S. Army 1993, 1994). The most common type of flood is the result of a major rainfall or snowmelt. A second type of flood happens suddenly, as in the case of dam failures or intense rainfall that generates a flash flood. A third category of flood results from an ice or debris jam.

a. Flood stages during an ice jam (Figure 10-1) can increase more rapidly and attain higher levels than those associated with open-water conditions. Ice jam flooding may take place outside the regulatory floodplain, often when the river flow would not otherwise cause problems. Although no specific damage figures are available, it is estimated that ice jams cause over $100 million in damages annually in the United States. Roads may be flooded and closed to traffic, and bridges weakened or destroyed, limiting emergency and medical relief to the affected areas. The potential exists for death or serious injury from jam and flood conditions, or during evacuations. Ice covers and ice jams also block hydropower and water supply intakes; delay or stop navigation; damage riverine structures, such as locks, dams, bridges, dikes, levees, and wingwalls; and decrease downstream discharge. In addition, ice movement and ice jams can severely erode streambeds and banks, with adverse effects on fish and wildlife habitat. Many laws and regulations have been developed to reduce national vulnerability to flooding.

b. Most American communities have floodplain regulations designed to prevent future development in areas subject to conventional open-water flooding. Some communities are protected by structural controls, such as dikes, levees, and flood control dams. Mitigation measures specifically designed to protect against ice jam flooding are used less commonly.

Figure 10-1. March 1999 breakup ice jam, Tunbridge, Vermont.

10-2. Ice Jam Flooding

In many northern regions, ice covers the rivers and lakes annually. The yearly freezeup and breakup commonly take place without major flooding. However, some communities face serious ice jam threats every year, while others experience ice-jam-induced flooding at random intervals. The former often have developed emergency plans to deal with ice jam problems, but the latter are often ill-prepared to cope with a jam. In a 1992 survey, Corps District and Division offices reported ice jam problems in 36 states, primarily in the northern tier of the United States (Figure 10-2). However, even mountainous regions as far south as New Mexico and Arizona experience river ice. Of the 36 states, 63 percent reported that ice jams occur frequently, and 75 percent rated ice jams as being serious to very serious (White 1992). Ice jams affect the major navigable inland waterways of the United States, including the Great Lakes. A study conducted in Maine, New Hampshire, and Vermont identified over 200 small towns and cities that reported ice jam flooding over a 10-year period (U.S. Army 1980). In March 1992 alone, 62 towns in New Hampshire and Vermont reported ice jam flooding problems after two rainfall events. Table 10-1 lists some of the major ice jams recently recorded.

Table 10-1
Recent Major Ice Jams in the United States

Place	*Date*	*Type (Damages)*
Safe Harbor, Pennsylvania	March 1996	Breakup (>$14 million)
Western Montana	February 1996	Breakup (>$2 million)
Ashland to Columbus, Nebraska	March 1993	Breakup ($25 million)
Montpelier, Vermont	March 1992	Breakup ($5 million)
Allagash, Maine	April 1991	Breakup ($14 million)
Mississippi River/ Missouri River Confluence	December 1989	Breakup (>$20 million)
Salmon, Idaho	February 1984	Freezeup ($1.8 million)
Port Jervis, New York/ Matamoras, Pennsylvania	February 1981	Breakup ($14.5 million)
Ashland to North Platte, Nebraska	February 1978	Breakup ($18 million)

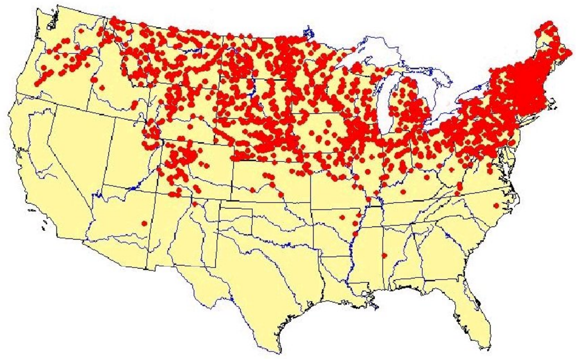

Figure 10-2. Ice events in the continental United States reported in the CRREL Ice Jam Database.

a. Characteristics of Ice Jams and Ice Jam Flooding. Because ice jam floods are less common and more poorly documented than open-water floods, it is more difficult to characterize these events compared to open-water flooding. In addition, because of the complex processes that cause ice jams to form and progress, and the highly site-specific nature of these jams, these events are more difficult to predict than open-water flooding. The rates of water level rise can vary from feet per minute to feet per hour during ice jam flooding. In some instances, communities have many hours of lead time between the time an ice jam forms and the start of flooding. In other cases, the lead time is as little as 1 hour. Although the actual time of flooding may be short compared to open-water floods lasting days to weeks, significant damage can result. The winter weather that often accompanies ice jams also adds to the risks and damages caused.

b. Example from Montpelier, Vermont, 1992. In March 1992, an ice jam developed at 0700 in Montpelier, Vermont. By 0800 the downtown area was flooded (Figure 10-3). During the next 11 hours, the business district was covered with an average of 1.2 to 1.5 meters (4 to 5 feet) of water. The flood happened so quickly that there was not sufficient time to warn residents so that they could protect their property and possessions. Even after water levels dropped, damage related to the flooding continued as cold weather caused freezing of wet objects. Damages of less than 1 day were estimated at more than $5 million (FEMA 1992b).

a. Winooski River.

Figure 10-3. Views of Montpelier, Vermont, ice jam (March 1992).

b. Downtown area.

Figure 10-3 (cont'd). Views of Montpelier, Vermont, ice jam (March 1992).

10-3. Ice Jam Flood Losses

a. Loss of Life. Ice jam flooding is responsible for loss of life, although the number of fatalities in the United States is considerably lower than that from open-water flooding. The CRREL Ice Jam Database (White and Eames 1999) reports 22 ice-event related deaths. Six of these deaths occurred during rescue attempts. Other deaths have occurred when residents delayed evacuation until it was too late. Often, rescue attempts are carried out at night, with both flood conditions and large ice pieces present, increasing the danger. This was the case for the neighborhood containing the home shown in Figure 10-4; fortunately, no deaths or injuries were reported.

b. Dollar Costs. Ice jams in the United States cause approximately $125 million in damages annually, including an estimated $50 million in personal property damage and $25 million in operation and maintenance costs to Corps navigation, flood control, and channel stabilization structures.

Figure 10-4. Damage from January 1996 breakup jam, Saranac River near Plattsburgh, New York.

Figure 10-5. Towboats and barges in ice.

c. Interference with Navigation. Ice jams have suspended or delayed commercial navigation, adversely affecting the economy (Figure 10-5). Although navigational delays are commonly short, they may result in shortages of critical supplies, such as fuel, coal, and industrial feedstocks, and lead to large costs from the operation of idle vessels (U.S. Army 1981). The costs associated with delays and stoppages of navigation by ice are difficult to determine, as there appears to be no central clearinghouse for such information. A search of Corps reports and newspapers in the St. Louis District revealed damage estimates for only 5 years: 1909 (more than $80,000), 1951 ($760,000), 1958 ($961,000), 1962 (more than $800,000 in shipping alone), and 1977 ($6.75 million in structural damage and shipping). These are reported in contemporary dollars and, except for 1977, are thought to be conservative, as they do not include all types of damage (e.g., increased operation and maintenance, structural damage, loss of perishable goods, flood-fighting efforts, damage to towboats and barges, etc.). In many years, as was reported in 1977 (Cairo Evening Citizen 1977):

> The tow vessels are under tremendous economic pressure to get the river open and moving again [St. Louis District public information officer Mel] Doernhoeser said. He said that each day a vessel is tied up it could mean from $3–5,000 to the company… the inland water transport system transports about 16 percent of the total shipping in the nation and that some of the more valuable commodities are primarily shipped by boat. Many of the places where the barges are docked are inaccessible from land and that even if rail or trucking facilities could reach them, they would not be able to handle the excess cargo…[since] one barge holds 15 rail cars of cargo.

Ice jams also cause structural damages to dams, gates, locks, mooring areas, and fleeting areas. Ice-related damage can occur even when ice is not the actual damaging force, as was the case in 1962. That year a large ice jam formed on the Mississippi River, trapping about 250 barges near Cairo. Somehow, a group of barges came loose, creating a domino effect that eventually loosed over 150 barges, sinking at least two, damaging harbor facilities, and heavily damaging a tow boat in the rescue effort. Contemporary newspapers reported that at a cost of about $65,000 for each barge, and perhaps double that when the cargo was included, nearly $1 million in damages resulted. Both the Corps of Engineers and members of the navigation industry, in addition to the Coast Guard, have contributed time and resources to combat ice jams on the Mississippi and Illinois Rivers. Historical records contain numerous reports of towboats, including those operated by the Corps, attempting to loosen ice and create navigation channels. Figure 10-6 shows a typical operation: two tows breaking ice in a lock forebay. In 1979, the cost of ice operations by towboats was estimated at about $1000 to $1500 per day, not including damage.

Figure 10-6. Towboats *H.L. Frieberg* (left) and *Dan Luckett* (right) breaking ice in the upper lock forebay, Lock and Dam 26, February 1966.

d. Reduced Power Production. Ice jams also affect hydropower operations, stopping hydropower generation by blocking intakes, causing high tailwater, making reduced discharge necessary, or damaging intake works (Figure 10-7). Lost power revenue attributable to such shutdowns can be substantial. In one such instance, power production at Oahe and Big Bend Dams (North Dakota) was curtailed during the period 10–12 January 1997 to avoid ice-related flooding in the Pierre–Fort Pierre area. Forgone energy generation was estimated at 6800 MWh, with a cost of about $270,000. Frazil blockage of intakes can affect other forms of power production in addition to hydropower. For example, in late January 1996, frazil ice blocked one, and partially blocked a second, emergency cooling water intake at the Wolf Creek Nuclear Power Plant located in Burlington, Kansas. This resulted in a plant shutdown, which in turn caused refueling to begin earlier than planned. It was estimated that the plant probably lost 2 to 3 weeks of power production because of the frazil blockage, at a cost of between $15 and $20 million.

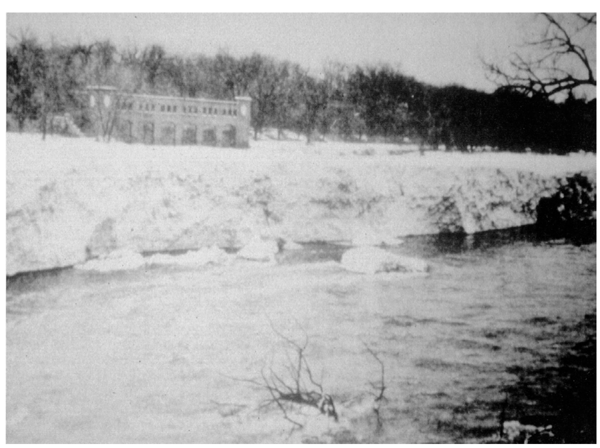

Figure 10-7. Jam immediately downstream of power plant, Fox River, near Ottawa, Illinois.

e. Channel Erosion and Damage to Channel Training Structures. The presence of an ice cover or ice jam can result and river bed scour and bank erosion that may lead to bridge or river bank failure (Figure 10-8). Winter monitoring on the upper Missouri River in Montana revealed nearly 12 meters (40 feet) of bank loss at one location during the ice-covered period of the winter of 1998–1999. Over a half meter (2 feet) of ice-induced bed scour was measured at a nearby site during the breakup period (Zabilansky and Yankielun 2000). Ice jams can damage stream channels and improvements, so that the overall vulnerability to flooding is increased. Riprap can be undermined or moved out of place. Ice-jam-related damage to river training structures costs millions of dollars each year. White (1999) reports that damage to river training structures near the Mississippi–Missouri confluence cost approximately $10 million as a result of the December 1988–January 1989 ice jam.

f. Indirect Costs. Ice jams can destroy fish and wildlife and their habitat, such as eagle roosting trees, and they can mobilize toxic materials buried in sediment. For example, the February 1996 Blackfoot River ice jam in Montana mobilized bed sediments containing high concentrations of mining wastes that are toxic to fish. This event resulted in a significant fish kill (Eames et al. 1998). As with any natural process, some of the scour associated with ice jams may be beneficial to wildlife habitat. Shallow, vegetation-choked wetlands may be opened, allowing for fish and waterfowl spawning and brood habitat.

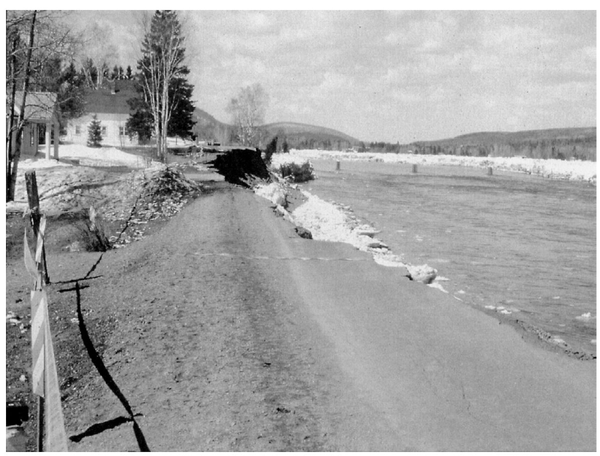

Figure 10-8. Bank scour caused by a breakup jam near Dickey, Maine.

10-4. Ice Jam Database

a. While much information has been collected and compiled for open-water floods, documentation on ice jams and other ice events, such as freezeup and ice cover breakup, is not often readily available in the United States. Additionally, while open-water stage can be determined at a site by flood routing from other sites upstream or downstream, the complex nature of ice jams requires highly site-specific methods of estimating flood stage. The relatively small quantity and limited availability of ice event data reflect the facts that ice events usually occur less frequently, are of shorter duration, and adversely affect only short reaches of river, compared to open-water floods, which can affect long reaches for up to several weeks.

b. In the past, the lack of readily available information on historical ice events has hindered the rapid, effective response to ice jam flooding and other ice-related damage. Collecting information specifically related to ice events, such as stage, flooded area, and previous mitigation methods, has generally required a time-consuming search of a variety of potential data sources. During emergencies, this is rarely possible. Information that might have assisted the emergency response effort may not be found until after the event, if at all.

c. The need for an accessible collection of ice data was particularly evident to personnel in the U.S. Army Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory (CRREL), Ice Engineering Research grou), who are involved in research on the hydraulics of ice, including ice cover formation and breakup, bed and bank erosion caused by ice, ice effects on riverine structures, and ice jam initiation, prediction, mitigation, and control, and who are called on to advise during ice jam flooding emergencies. The CRREL Ice Jam Database was developed in response to this need (White and Eames 1999). The database provides quick access to general information on nearly 12,000 specific ice jam events in the United States. These historical data are crucial during emergency situations where information about jam locations or stages would be helpful. Database entries include the name of the water body; the city and state where the ice event took place; the month, year, and date of the ice event; the ice event type, if known; a brief description of damage; the names of IERD and Corps personnel familiar with the event or site (points of contact); whether IERD files contain visual records of the event; latitude and longitude; the USGS gage number, if available; and hydrologic unit code. Records also contain narrative descriptions of ice events (which can be several pages long) and a list of information sources. There is a separate database entry for each discrete ice event at a given location.

d. The CRREL Ice Jam Database is constantly enlarging as historical ice event data are collected and entered. It is maintained by IERD personnel using the ORACLE database manager. The inclusion of geographical information will allow future development of GIS applications. USGS hydrologic unit codes allow searches by Corps Districts and Divisions, many of which are delineated by watershed boundaries. The database may be accessed via the CRREL web site at http://www.crrel.usace.army.mil. The user interface allows for database queries that are displayed in a manner that allows additional data screening and processing.

e. This new database is useful, not only as a centralized record of ice events, but also for the many potential applications of the information. These include rapid identification of potential ice jam stages, flooded areas, and mitigation methods at some known ice jam locations. The listing of sources and contacts may aid in the search for additional information about particular ice events. The ice event data provided can be evaluated with other meteorological and hydrological data to characterize the conditions most likely to cause ice events at a particular location. The database is useful for reconnaissance level evaluation, for detailed studies of a problem area, and for designing ice control techniques, as well as for emergency responses to ice jam events. CRREL plans to prepare summaries of ice jam data for all affected states and has completed brief summaries for New Hampshire and Vermont (White 1995), Alaska (Eames and White 1997), and Montana (Eames et al. 1998) to date. Annual ice jam summaries are available beginning in 1996.

10-5. References

a. Required Publications.

None.

b. Related Publications.

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